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By Janos Nuridsany

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SEVERAL PROBLEMS CONNECTED WITH THE CHEMICAL DISINFECTION OF AIR

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Microorganisms in the Air

There are normally several species of saprophytic microorganisms in the air, such as cocci, sarcinae, fungi, etc., which are most resistant to dessication and other climatic effects than the pathogenes detrimental to human beings. In air strata high above ground level, fungi constitute the majority of microorganisms, whereas bacteria are more common near the ground. The rapid decrease in the number of microbes at high altitudes had been observed by Pasteur. Near the ground, however, fungi constitute about twice the number of microbes. Pathogenic microorganisms are encountered in the air primarily in residential areas and in buildings; without interference their number is directly proportional to the dust content of the air (1).

The flora of the sinuses, mouth cavity and skin is very important in the qualitative analysis of microorganisms in the air. The number of these bacteria or pathogenes per volumetric unit signifies the degree of air contamination. In complex sanitary analyses of room air it has been observed that if the ambient temperature, humidity and carbon dioxide contents do not substantially change, microbes are primarily responsible for air deterioration. In crowded rooms where temperature, humidity and carbon dioxide content are above sanitary norms, a considerable increase of microbes can be perceived (1).

In room air -- in contrast to free air -- the microflora exhaled from the human respiratory system becomes greatly concentrated, especially if ventilation is poor. This condition and other factors can effectively increase the number of microorganisms. In room air the degree of contamination is basically the same as in free air; here, however, the microbes perish relatively faster than in rooms

being subjected to dessication by the sun, wind, etc. In the battle against contagious diseases, the most important task is to prevent the epidemic from spreading, as well as to isolate the epidemic source and to immunize susceptible subjects. In the case of certain epidemic diseases, spreading can be prevented by relatively simple measures (washing the hands, disinfecting secretions and excrements, etc.). In rooms, however, the danger of aerogenic infection can be reduced most effectively by the disinfection of air.

By sneezing, coughing, and even by talking, a large number of small drops containing microorganism are ejected into the air (1, 2). These drops are capable of floating in the air for a prolonged time and can travel considerable distacnes by even the smallest air movements. The microorganisms are present in the air in aerosol forms. (An aerosol form is a colloid in which gas is the dispersion medium, for example, air with dispersed solid particles and fluid drops in it.)

The properties of the dispersed aerosol form depend on the size, surface energy and electric charge of the particles and on the characteristics of the dispersion medium. In the case of particles larger than 100 microns the force of gravity is greater than the air resistance, and therefore these settle down much faster than do those smaller than 100 microns, which are able to float depending on the air movements involved.

The dynamic dispersion of bacterium aerosols in the air depends on the kinetic energy of particles ejected from the human respiratory system, in other words, on their initial velocity and size. In the case of equal initial velocity the larger particles travel a greater distance. An enormous number of drops can be formed by sneezing or by strong exhalation. Even if the person sneezing is normally healthy, a vast number of microorganisms are dispersed in the surrounding air which can be rapidly propagated by air currents and breezes. Artificially dispersed bacterium aerosols also spread rapidly throughout a whole building.

Wells (3) has introduced some coli bacteria into the air-conditioning system of a three-story building. Shortly afterwards, the coli bacteria became detectable in the air of all three floors. The propagation of microorganisms can take place even in free air. This fact has

been proven by Trill in the following experiment: one liter of a liquid containing prodigiosum bacteria was dispersed in a closed court; 100 gelatin plates were placed on the circumference of a circle with a radius of 100 meters around the place of dispersion. After incubation the prodigiosum colonies grew on every plate except for Those in the direction of the wind (1).

In free air the aerosol concentration decreases rapidly; consequently, aerogenic infection plays a much less important role than in enclosed areas.

Methods of Determining Bacterial Content of the Air

In enclosed areas disinfection of the air must be based on actual measurements of air contamination. The properties of the air in a given room must be known in order to serve as a basis for determining the method, time and duty cycle (continuous or intermittent) of disinfection to attain optimum results.

The effect of air disinfectants is generally checked by determining the number of microorganisms present in the air. The oldest method for measuring the germ count is the Koch sedimentation process (2, 4). The disadvantage of this procedure is that it is based exclusively on sedimentation; consequently, its application is limited to larger microorganisms.

The electrostatic process is similar to that mentioned above; however, in it the sedimentation of microorgansims takes place in an electric field, assuring an increased efficiency factor (5).

Countless other methods have been found to determine the germ count of fluid mediums (39). In these processes a predetermined amount of air is pumped through the fluid medium; samples of this medium are diluted and inoculated to gelatine plates on which the germ count is determined (6, 7).

For informative investigation the new membrane filter method has been successfully adopted (8).

The best instrument for determining the germ count of air is the so-called slotted sample, first used by Bourdillon. It operates in the following manner: High-speed air of predetermined quantity is pumped through a

very narrow slot onto a Petri plate containing a culture medium. The Petri plate is located directly under the slot and can be rotated for a preset time with variable speed. This way the effect of the disinfectant can be closely followed as a function of the time (9, 10).

Aseptic Conditions of Air Disinfection (Sterile Operation)

Sterilization of the air is very important in places where a low germ count must be maintained throughout the working cycle. It is well known that the aerogene route bears a great significance in the propagation of contagious diseases. For many of the diseases such as grippe, measles, etc., this route is almost the only way of spreading. The aerogenic way is also primarily responsible for the spread of tuberculosis. The possibility of dust and drop infections, a route discovered by Cornet and Flugge (11), has given primary impetus to world-wide research in air microbiology. Today this problem is quite timely not only for the prevention of epidemic disease but also in other fields, such as in the production of vaccines and drugs, sanitary packing and storing of various foodstuffs, etc., all of which demand a "steirle" atmosphere, or at least one relatively free of microorganisms.

The So-Called Sterile Room

In designing so-called sterile rooms the most important consideration is to assure their easy cleaning so that with the available disinfectants and sterilizing equipment all possibilities of contact infections can be ruled out. The floor, walls and ceiling of these premises must be lined without gaps; for these the proven method of scrubbing with disinfectants such as formaldehyde or phenol should be applied. Painting the walls and ceiling with oil paint is particularly advantageous; according to Heichen (30) these architectural members have a special germicidal feature if scrubbed with phenol.

It is also very important that employees working in the "sterile room" take care of their individual hygiene, performing the specified washing procedures and wearing the specified sterile clothes, face cloths, or suitably fastened hoods covering the head and face, rubber gloves and sterile canvas shoes.

Cleanliness of the equipment deserves special attention. If the installations are not periodically cleaned and steri-

lized, they represent a constant danger of infection. For instance, according to J. Koch, about15,000 microbes per square centimeter can be found on the inner wall of rubber tube adaptors or hoses. Similarly, the number of microorganisms in cracked tubes is 75,000 per square centimeter and in that of mouldy-smelling tubers about one million per square centimeter (31).

"Sterile rooms" must be equipped with hermetically closed windows and doors. Doors must open on the inner "sterile" corridor of a double corridor system. Air must be supplied by a ventilation system containing an oil or cotton filter and several germ reducing Zeiss- or-resin-bounded glass wool filters. According to many authors, the effectiveness of the filters is enhanced by ahigher air speed (32). Sterilization of the air is generally undertaken in two steps. First, the aerosol content is reduced by mechanical filters. This reduction serves as a "coarse sterilization." In the second phase, disinfectants are used for further sterilization.

Chemical Disinfectants, Their Application and Effects

Disinfectants used for air sterilization must not irritate the mucuous membranes or cause symptoms of poisoning; materials with these inherent irritating properties must not be used.

Chemical disinfectants generally used for air sterilization belong to the glycol family. The glycols are clear, odorless, nontoxic, sweet tasting, viscous, corrosion free, noncombustible hygroscopic chemicals. Triethyleneglycol is most widely used (12) for air sterilization, although propyleneglycol (13) and ethyleneglycol (14) are also popular.

In the in vitro investigation of glycols it has been found that they need to be highly concentrated to achieve the desired bactericidal effect. Monomethyldiethyleneglycol has proved to be most effective, for about 10 percent concentration was sufficient to kill the bacteria.

On the basis of past investigations we can conclude that the air-sterilizing effect of glycols is independent of the in vitro effect, since an aqueous solution of triethyleneglycol diluted 1 to 250 million is capable of killing (14, 17, 18) staphylo-, strepto- and pneumococci, diphtheria, tuberculosis and prodigiosum bacteria, common cold and mumps viruses in 10 to 15 minutes. Its bacteri-

cidal effect can be observed even if diluted in a 1 to 500 million ratio. The effective concentration of triethyleneglycol has been given in 0.5 to 5 gamma per liter by different authors (13, 17, 19, 20, 21, 22, 23), although concentrations higher than the above indicated are still nontoxic. From the viewpoint of effectiveness, increasing the concentration is limited by the fact that under normal conditions of humidity, and above a certain limiting value triethyleneglycol irritates the mucous membranes (24).

In order to utilize the glycols most effectively, they have to be introduced to the air in a specified way, such as by steam, gas, spray or mist forms. The optimum evaporation temperature of triethyleneglycol is 127 degrees (19). Experiments have proved that glycols are most effective in mist form. The Glycostat, Aerosol, Defensor, etc., type of equipment is best suited to produce a glycol mist. The temperature and humidity (29) of the air must be checked continuously when operating these machines. For best bactericidal action it is important to adjust the optimum temperature and relative humidity conditions of the air. The most effective operation has been achieved with 20 to 25 degrees and 45 to 80 percent (19, 20, 25, 26).

It has not yet been revealed why glycols are so effective in air sterilization. The bactericidal action in the air does not coincide with the <u>in vitro</u> effect (14, 17, 18). According to the latest information, the fact that the small hygroscopic particles of glycols settle down on microbes, diffuse through the cellular membrane and kill them seems to be an acceptable explanation. However, it is still a question how the electric charge of the disinfectants and bacterium aerosols influence the attraction of particles, the surface accumulation. Experiments have shown that disinfectant sprays are more effective for air sterilization than either the steam or vapor forms. The explanation for this is that in spraying, more active particles are introduced to the air in a shorter time or in the same time.

The sterilizing effect of propyleneglycol (13) is similar to that of the triethyleneglycol. Experiments have proved that by spraying, bacteria had been killed within 30 minutes. If after the propyleneglycol treatment formaldehyde was also sprayed, bacteriological tests have shown complete sterilization of the air (28). In this case the formaldehyde mist can be neutralized by ammonia, and shortly after sterilization the room is ready for use.

The excellent bactericidal effects of ethyleneglycol have been observed when it was used in conjuction with other sterilizing materials. Best results have been achieved by applying a mixture of ethyleneglycol, resorcinol, alcohol and water (27). Owing to the low viscosity factor of the alcohol, the Brownian motion of the particle increases together with the bactericidal action. Experiments have shown that, by using the above mentioned mixture, bacteria of different resistance can be surely killed within 40 minutes, such as staphylococci, diphtheria, coli, prodigiosum, yeast fungi, etc (27).

The effectiveness of air sterilization depends on the number of persons present in the area to be sterilized and on the application of other precautions mentioned. If coughing, sneezing or even talking occurs in the already sterilized area, new aerosol drops can introduce infection. It is well known from field practice that these contaminations can be overcome by obeying the strict rules of sterile clothing. The hood of multilayer face cloth, fastened in the specified way, substantially reduces aerosol infection. Whether chemical air disinfectants have any bactericidal action on bacteria thriving on beds, walls and other objects is still disputed. Experiments and bacteriological tests have proved that after four hours of continuous sterilization, complete disinfection can be achieved, including floors, walls, and objects(28).

Besides the above mentioned chemicals, lactic acid can also be effectively used as an air disinfectant (33). Lactic acid can be applied in spray or vapor form at an optimum evaporation temperature of 150 to 180 degrees (9,34). However, evaporation should be carried out carefully, because lactic acid can easily break down to lactic acid anhydride, an irritant to human beings but an ineffective agent against bacteria. About 94 percent of artificially sprayed staphylococcus albus can be killed in 10 minutes by 10 milligrams per cubic meter of evaporated lactic acid. In an hour the lethal effect is 99.6 percent. If a 5 to 10 percent lactic acid solution is sprayed into the air, an 8 milligrams-per-cubic-meter lactic acid concentration can kill about 88.6 percent and in 15 minutes about 99 percent of the examined staphylococci (34). Its effect is practically independent of relative humidity. In the above mentioned concentration lactic acid is nontoxic, and under normal conditions it is present in the human body. The effectiveness of the similar levulin was also investigated (9). This chemical

is one of the by-products of sugar refineries and is turned out in great quantities. However its air-sterilization ability is less than that of lactic acid.

Several gases have also been tried out for air sterilization. Best results have been achieved by ethyleneoxide (37, 38). Experience has shown that it is effective on all kinds of microorganisms, by penetrating into porous materials. It can also be easily removed from the materials thus treated. However, its sterilizing action is rather slow: another disadvantage is its combustibility. A three percent mixture of ethyleneoxide with air constitutes a dangerous explosive; this hazard can be avoided by the addition of 10 percent carbon dioxide.

Besides those mentioned, a large number of chemicals have been tried out for air sterilization. Such materials, for instance, have been aromatic vegetable oils, turpentine, camphor, etc. However, their significance is mostly therapeutic, primarily in treating illnesses of the upper respiratory system (41).

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